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Interindividual differences in general cognitive ability from age 18 to age 65 years are extremely stable and strongly associated with working memory capacity

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ABSTRACT

The objective of the study was to examine the degree of stability of interindividual differences in general cognitive ability (g) across the adult life span. To this end, we examined a sample of men ($n = 262$), cognitively assessed for the first time at age 18 (conscript data). The sample was reassessed at age 50 and at five year intervals up to age 65. Scores from conscript tests at age 18 were retrieved and three of the subtests were used as indicators of g in early adulthood. At age 50–65 years, four indicators served the same purpose. At the 15-year follow-up (age 65) two working memory measures were administered which allowed examination of the relationship with working memory capacity. Results from structural Equation Modelling (SEM) indicated extremely high level of stability from young adulthood to age 50 (standardized regression coefficient = −95) as well as from age 50 to age 55, 60 and 65 with stability coefficients of .90 or higher for the for the latent g factor. Standardized regression coefficients between young-adult g and the g factor in midlife/old age were .95 from age 18 up to age 50 and 55, .94 up to age 60, and .86 up to age 65. Hence, g at age 18 accounted for 90–74% of the variance in g 32–47 years later. A close association between g and working memory capacity was observed (concurrent association: $r = .88$, time lagged association: $r = .61$). Taken together, the present study demonstrates that interindividual differences in g are extremely stable over the period from 18 to midlife, with a significant deviation from unity only at age 65. In light of the parieto-frontal integration theory (P-FIT) of intelligence, consistent with the close association between g and working memory capacity, midlife may be characterized by neural stability, with decline and decreased interindividual stability, related to loss of parieto-frontal integrity, past age 60.

1. Introduction

A general cognitive ability (g) factor has been proposed to account for the “positive manifold” observed across a variety of cognitive measures (Jensen, 1998; Carroll, 1993; Spearman, 1904). The g factor is important for certain aspects of life-success, as judged by associations between proxy measures (IQ scores) and later achievements, for example, educational attainment, job performance, and socioeconomic status (Deary, Whiteman, Starr, Whalley, & Fox, 2004; Strenze, 2007).

An important issue concerns to what degree interindividual differences in the g factor are stable over the life course. As noted by Deary, Whalley, Lemmon, Crawford and Starr (2000), it is of interest in childhood to discover whether educational interventions boost ability levels and whether adverse environmental factors lower cognitive functions. Stability estimates in the period from early adulthood to old age should similarly be informative of the extent to which individual differ in cognitive ageing. Given that individuals are differentially exposed to a myriad of factors that potentially influence cognition, one might expect the stability of individual differences from youth to late adulthood to be rather moderate.

However, contrary to this expectation, several studies indicate considerable stability of individual differences in IQ-test performance over long time periods (for an exception see Plassman et al., 1995). For example, in a study by Owens (1966), 96 freshmen at the Iowa State University took the Army Alpha, a group test originally developed to evaluate military recruits, when they were 19 years old and were retested 42 years later. The correlation between the initial and follow-up test scores was as high as .78, suggesting that about 60% of the variance in ability at age 61 was predictable from test scores age 19. More recently, Deary et al. (2000) examined a group of 101 adults who took the Moray House Test when they were 11 years old and were retested 66 years later, at age 77. The test–retest correlation was 0.63 and boosted to 0.73 when restriction of ability

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range at retest was adjusted for, suggesting that up to half of the variance in ability at age 77 was accounted for by adolescent performance. A further study involving the same intelligence test reported a coefficient of 0.54 from age 11 to age 90, with a value of 0.67 when restrictions in range were corrected (Deary, Pattie, & Starr, 2013). As discussed by the authors, the reported values may actually be an underestimate of stability of interindividual differences due to measurement error (i.e. lack of perfect reliability of the test).

In the present study we further examined the long-term stability of general intelligence, targeting the period from early adulthood to young-old age. We examined a group of men for whom we retrieved data from conscript testing at age 18. At age 50 study group took several cognitive tests as part of a longitudinal study on ageing and cognitive functions (Nilsson et al., 1997; 2004). A longitudinal follow-up of the tests at age 50 was furthermore made five, ten and fifteen years following the midlife assessment. Hence, the extent to which ability at age 18 was predictive of ability at age 50, 55, 60, and 65 years could be compared based on data from the same study sample and the repeated testing at higher ages allowed for examining the stability coefficients across a range in which cognitive functions generally dip longitudinally (e.g. Rönnlund, Nyberg, Bäckman, & Nilsson, 2005; Schaie, 1994). Importantly, even though different cognitive tests were administered in early and late adulthood, with three or more indicators of general ability at age 18 and at ages 50–65, the relationship between early and later cognitive ability could be examined at the latent ability level, rather than, as in the aforementioned studies, for manifest test scores which confound stability with measurement error, and hence tend to underestimate stability at the construct level. Finally, we examined the concurrent (at age 65) and time-lagged relationship between general ability and working-memory capacity, measures that were added to the battery at the fifteen-year follow-up. Working memory capacity has in prior studies (e.g. Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Kyllonen & Christal, 1990; Unsworth, Fukuda, Awh, & Vogel, 2014) been found to be substantially associated with general intelligence, and measures of fluid reasoning (Gf) in particular.

2. Method

2.1. Participants

The included participants were enrolled in the Betula prospective cohort study, a longitudinal study of memory and health in Umeå, Sweden. The study started in 1988 and involves randomized sampling from the population register in Umeå community (Nilsson et al., 1997; 2004). At the second test occasion (T2; 1993–1995), considered as baseline in the present study, three subsamples were involved: Sample 1 (S1; 40–85 years), Sample 2 (S2; 35–80 years), and Sample 3 (S3; 40–85 years). For participants in S1 and S3, a longitudinal follow-up was made five (1998–2000), ten (2003–2005), and fifteen years (2008–2010) later.

Following approval from a regional ethic committee, we retrieved cognitive test scores for a subset of the participants in S1–S3 from the archive containing information gathered at draught boards (The Swedish military archives). Targeted were those participants expected to have taken the conscript tests during a period from 1954, when standardized scores were registered for each subtest and for total performance, and up to 1967. For 432 of the 435 participants (99.3%) the data were successfully retrieved. The present study sample involved 262 participants in S1 and S3 who were 45, 50, or 55 years (approximately 1/3 at each of the age levels) at baseline.

2.2. Measures

2.2.1. General cognitive ability — Swedish enlistment battery

Depending on birth cohort, each participant had taken one of two versions of the Swedish Enlistment Battery (SEB). The first, SEB-1954 ($n = 82$), involved five tests: Instructions, Concept discrimination, Technical comprehension, Levers, and Multiplication. Descriptions of the tests and standardized loadings (SL) on a general and specific ability factors are adopted from Carlstedt (2000; see Table 1, p. 35 for loadings based on confirmatory analyses, that also included other tests). Labelling of factors are adopted from Schneider and McGrew (2012), were g = general ability, Gf = fluid reasoning, Gc = comprehension-knowledge; Gv = visual processing, and Glr = Long-term storage and retrieval.

The Instructions test, intended to measure the primary factor Induction, a narrow ability within Gf (Schneider & McGrew, 2012) mainly reflected g (SL on $g = 0.77$; Gc = 0.19). This test contained verbal instructions to make markings on the answer sheet that fulfilled the conditions provided by the instructions. Item difficulty was manipulated by complexity of the instructions and by distractive negations or conditional clauses. Concept Discrimination involved classification of words (SL on $g = 0.67$; SL on Gc = 0.30). Technical comprehension involved a set of illustrated technical and physical problems and reflected g, Gc, as well as Gv; Carlstedt, 2000). Levers was a mechanical reasoning test with main loading on Gv (SL = 0.58; SL on $g = 0.43$). Multiplication, finally, was found to reflect a "Math" factor (SL = 0.54) apart from g (SL = 0.67).

In the second version, SEB-1959 ($n = 180$), that replaced the SEB-1954, Instructions, Concept discrimination and Technical comprehension were retained. Multiplication was excluded, and the Levers test was replaced by Paper form board. The latter test involved judgments of which target object out of four would be correctly put together by a set of disarranged parts of objects and reflected g and Gv (Carlstedt, 2000).

Regardless of SEB version, a standard-nine score (M = 5, SD = 2) was provided for each subtest together with a total score based on the sum of the standardized subtest scores. In the present analyses we used a composite measure created by averaging the standard-nine scores of the 4–5 (depending on SEB version) subtests. Further, we used the three tests common to both SEB versions (Instructions, Concept discrimination, and Technical comprehensions) as indicators of a general ability factor. A principal components analysis (PCA) of all data available for SEB-1959 (S1-S3; $n = 147$) showed that the foregoing three test were those with the highest loadings on a single component with eigenvalue >1 (0.88 for Instructions, 0.82 for Concept discrimination, and 0.76 for Technical comprehension) that accounted for 57.0% of the variance in test scores.

2.2.2. General cognitive ability — the Betula battery

Judgments based on content, including a wish to include verbal as well as nonverbal materials and a wish to tap different factors at the stratum II-level (Carroll, 1993), served as a basis for selecting four indicators of general ability. The first indicator was raw scores on the WAIS-R Block Design test (BDT; Wechsler, 1981) which may be regarded to reflect g/Gv. Cronbach's α for the BDT in a large Swedish sample was .82 (Rönnlund & Nilsson, 2006a). The second measure was scores on a 30 item multi-choice vocabulary (VOC) test (Dureman, 1960) which should reflect g/Gc. Split-half (Spearman–Brown) reliability of .82 was reported for this measure (Rönnlund & Nilsson, 2006a). The third measure, action recall (ARC) was computed as the sum of two free recall trials involving 16 action phrases (e.g. "Lift the book") enacted at study, and 16 action phrases with no enactment at study (Rönnlund, Nyberg, Bäckman, & Nilsson, 2003), regarded to reflect g and Glr (associative memory and free recall). Split-half coefficient for the separate trials/conditions were .63 and .62 (Rönnlund & Nilsson, 2006a) and a five-year test–retest correlation of the sum of these was $r = .60$ in the present sample. Finally, a measure of word fluency (WFL) was computed as the sum of two phonemic fluency tests that involved oral generation of as many words as possible during one minute. The restrictions were i) words with initial letter A and ii) words with initial letter M containing five letters. The measure should reflect g/Glr

Table 1
Background characteristics at baseline for the total sample and for the returnees and dropouts at the 5-year, 10-year and 15-year follow-up measurements.

	Total	5-year follow-up		10-year follow-up		15-year follow-up	
		Returnees	Dropouts	Returnees	Dropouts	Returnees	Dropouts
n	262	240	22	208	54	176	86
Age	49.9 (4.1)	49.9 (4.1)	49.1 (3.6)	49.9 (4.1)	49.6 (3.9)	50.1 (4.0)	49.5 (4.1)
Edu (years)	12.2 (3.9)	12.2 (3.8)	13.3 (4.5)	11.9 (3.8)	13.3 (4.2)*	12.3 (3.8)	12.1 (4.0)
GAS (age 18)	5.7 (1.7)	5.7 (1.7)	6.1 (2.0)	5.6 (1.7)	6.1 (1.7)	5.7 (1.7)	5.7 (1.7)
BDT (age 50)	12.3 (2.8)	12.2 (2.8)	12.6 (3.1)	12.2 (2.8)	12.5 (2.9)	12.3 (2.8)	12.1 (2.9)
Voc (age 50)	23.4 (3.8)	23.4 (3.8)	23.5 (3.4)	23.3 (3.8)	23.8 (3.4)	23.7 (3.5)	22.8 (4.2)

Edu = education, GAS = general ability score (standard-nine), BDT = WAIS-R Block Design Test (scaled scores), Voc = vocabulary test.
* $p < .05$ for the difference between returnees and dropouts as determined by an independent samples t-test.

(retrieval fluency). A five-year test–retest correlation of $r = .70$ was observed for this measure.

A PCA of baseline data ($n = 262$) confirmed that the four measures reflected a single factor (eigenvalue > 1) that accounted for 52.3% of the variance. A confirmatory factor analysis with the four measures as indicators of a general ability factor yielded a non-significant value for χ^2 $(2) = 0.60$, $p = .55$, indicating that the fit of a unitary model was adequate.

2.2.3. Working memory capacity — the Betula battery (15-year follow-up)

Two measures were used as indicators of working memory capacity. The first was a computerized version of reading span, jointly tapping the storage and processing functions of working memory (Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001). This task involves multiple trials with an ascending number of items to be kept in memory. Serial recall performances at the end of each trial provide the basis for indexing working memory capacity. Span level, computed as the maximum level for which the participants succeeded all three trials plus the proportion correct words at the next level served as the dependent measure. The second test was a two-back test (McElree, 2001). This test involves forty words displayed sequentially on a computer screen. The participants are required to maintain the two most recent words and their temporal order in working memory to indicate whether or not the current word is the same as the one presented two items earlier. The proportion of correct judgments was used as the dependent measure.

3. Results

3. 1 Characteristics of the study sample and attrition analyses

Table 1 provides a summary of characteristics of the study sample. For each longitudinal follow-up (5, 10, and 15 years), separate values are provided for returnees and dropouts.

A majority of the participants returned for follow-up measurement 5, 10, and 15 years later, with a dropout rate of about 10% from each test occasion to the next. Further, there is little indication that the attrition was selective. Specifically, neither age, nor mean performance on the cognitive measures (general ability score, GAS, at age 18, Vocabulary and Block Design at age 50) differed as a function of retest status. The only significant difference between returnees and dropouts was for years of schooling, and only at the 10-year follow-up. Note though, that in this case, the dropouts had slightly more schooling than the returnees.

Whereas the dropout appeared to be largely non-selective, the mean GAS of 5.7 at age 18 for the sample as a whole is slightly above the population mean of 5.0 (SD = 2, $p < .01$ as determined by a one-sample t-test), as was also the scaled score of 12.3 on WAIS-R Block Design test (mean 10, SD = 3 based on US raw-score norms, $p < .01$). Even though a male advantage should be considered in the case of Block Design performance (Rönnlund & Nilsson, 2006b), these findings indicate that the sample was slightly above the population average in terms of ability level. No skewness (< 0.5) was evident for either of the two measures, though.

3.2 Relationship between g in early adulthood and at ages 50–65

In a first model the age 18 latent factor was regressed upon the g factor based on data at mean age of 50 (Model 1). In subsequent models, a longitudinal (autoregressive) sequence was added to the first model. The added sequence was based on the repeated administration of the same tests over a five-year retest interval (50 to 55 years). In Models 3 and 4, the stability coefficient was estimated for continuously longer test–retest interval (50–60 in Model 3 and 50–65 years in Model 4). For each of the longitudinal sequences autocorrelations were allowed for the error terms. The marker variable method was used to identify the factors. Factor loading were constrained to be equal across time, and separate analyses confirmed that imposing these constraint did not result in any substantial reduction of model fit as judged by criteria by Cheung & Renswold (2002), suggesting that the midlife g factor was time invariant in the metric sense. The indicators all had acceptable values of skewness (range: −1.05–0.35) and kurtosis (range: −0.47–0.96). Maximum likelihood estimates were used. Results pertaining to each of the four models are depicted in Fig. 1, including the standardized regression weights and standardized factor loadings.

As can be seen, the standardized regression coefficients/stability coefficients were very high throughout (e.g. .95 for the latent factor at age 18 and age 50, and .97 to .99 for the five and ten-year test–retest intervals in midlife (mean age 55 to 60 at follow up). In fact, only at the fifteen-year longitudinal follow up the estimated relationship (stability coefficient = .90) was significantly lower than unity as indicated by the emergence of a significant variance of the disturbance term (i.e for Model 4 but not for Models 2 and 3). The fit for Models 1–4 were good as judged by commonly adopted fit indices (e.g. CFI > −95 in all cases, and RMSEA = .048–.051 across the models). Standardized regression coefficients in parenthesis are for midlife factors with the vocabulary test omitted as an indicator of g. As can be seen from a comparison with the coefficients obtained using all four markers in Models 1.4, this method designed to obtain a more "fluid" g factor did not lower estimates substantially.

Whereas the foregoing analyses clearly show that the g factor is highly stable across fairly long segments of the life span (e.g. 18–50 years; 50 to 65 years) we wished to obtain estimates of stability for a longer period. To this end, we re-ran Models 2–4 omitting the age 50 factor, which provided estimates for the sequence 18–55, 18–60, and 18–65 years. Once again, the fit indices, including CFI (>.95 in all cases) and RMSEA (<.083 in all cases) were suggestive of a reasonable fit. The estimates of stability (i.e. standardized regression coefficients were, as should be expected on basis of the previous analyses very high (.95, 94, and .86 up to age 55, 60 and 65, respectively). The coefficient of .95 from general ability at age 18 to age 55 implies that about 90% of the variance in ability was accounted for by latent ability at age 18. For the test–retest intervals from 18 years up to 60 years, the variance for the disturbance term was not significant, much in line with

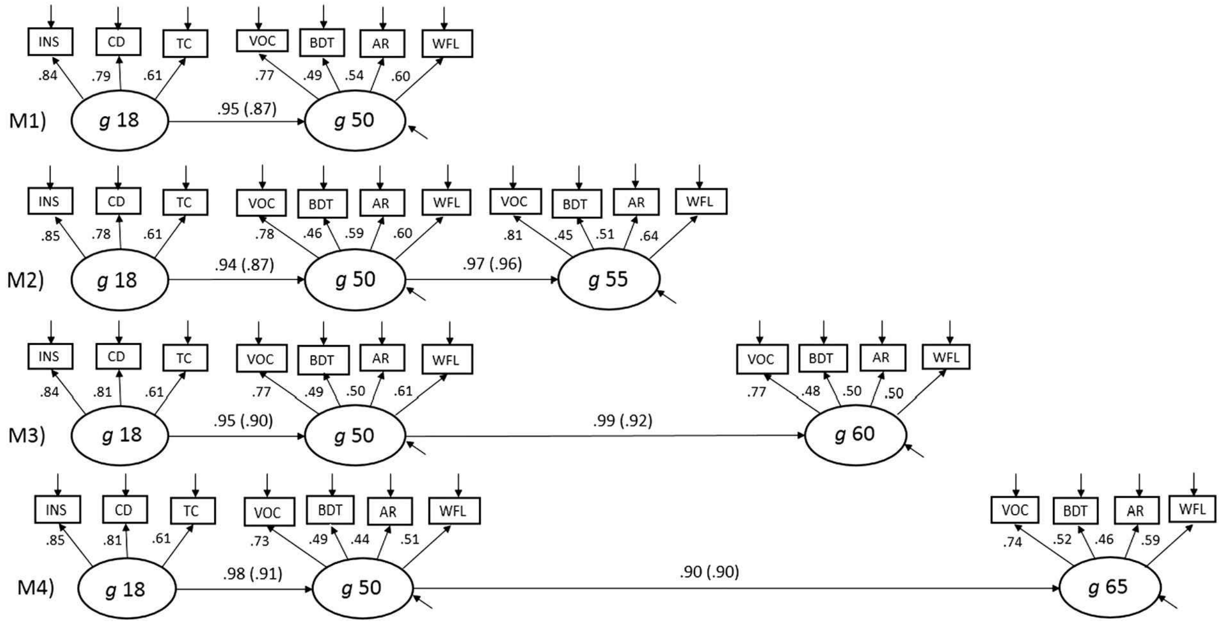

Fig. 1. Summary of results of structural equation models (Models 1–4) designed to estimate degree of stability of interindividual differences in adulthood.

the previous analyses. Additionally, a deviance from near-perfect stability of interindividual differences was discernible for the longest test–retest interval (18–65 years), though (variance of the disturbance term significant at $p = .02$). Note, though, that even at age 65, more than 70% of the variance in general ability was accounted for by the measurement 47 years earlier.

3.3 Concurrent and time-lagged associations with working memory capacity

Finally, concurrent (age 65) and time-lagged (age 18 vs. age 65) associations between working memory capacity (a latent factor based on two indicators: reading span and two-back) were examined in a model involving the three factors that were free to covary. Included were the participants at the fifteen-year follow-up who took the computerized WM tests ($n = 159$; 17 participants had, for various reasons, not taken these tests). The model fit was adequate, χ^2 (24) = 25.91, $p = .36$, CFI = .995, RMSEA = .021. The results, summarized in Fig. 2, revealed a strong concurrent ($r = .88$, $p = .01$) and time-lagged ($r = .61$, $p = .01$) association between the *g* and WMC latent constructs.

4. Discussion

The main objective of the present study was to examine the degree of stability of individual differences in *g* across adulthood. The results show that a very large proportion of the variance in a *g* factor in midlife and young old age is accounted for by *g* in early adulthood, with estimates ranging from about 90% at age 50 to over 70% at age 65. Our results are in line with previous studies (Deary et al. 2000; 2004; 2013; Owens, 1966) but demonstrate even higher estimates of stability of individual differences than might be expected based on prior research. This matter likely reflects the fact that the *g* factor was estimated at the latent level rather than, as in the foregoing studies, at the level of manifest IQ scores. In other words most previous studies likely underestimated the true stability of individual differences in intelligence due to the fact that deviation in correlations between manifest test scores from unity partly reflects measurement error rather than lack of stability of the interindividual differences. A recent study, that also used a structural equation modelling approach (Schalke et al., 2013), reported a stability coefficient of .85 for a general ability factor from age 12 up to age 52. The slightly lower value compared with that present estimate (up to age 50) possibly reflects the fact that measures of initial ability were obtained at a younger age than in the present study. Additionally, it is important to notice that omission of vocabulary, that may be expected to show particularly high stability of individual differences, as a marker of the midlife *g* factor did not substantially lower stability estimates, suggesting that very high stability is also observed for a *g* factor that is more fluid in nature.

The pattern of high interindividual stability up to age 60, and indication of lowered stability past this age, concurs with a pattern of stability and change of major cognitive abilities in a second sense, namely at the mean-level, even though it is important to realize that changes in interindividual stability and changes at the average group level do not necessarily covary (e.g. Hertzog & Schaie, 1988). More specifically, unlike cross-sectional studies that suggest an onset of decline already in the 20s (e.g. Park et al., 2002), longitudinal studies have demonstrated mean-level stability of several major cognitive factors up to about age 60, followed by accelerated decline. The foregoing patters are evident for measures of spatial ability (Rönnlund & Nilsson, 2006b; Schaie, 1994), episodic and semantic memory (Rönnlund, Nyberg, Bäckman, & Nilsson, 2005), numerical ability, inductive reasoning (Schaie, 1994), and for a general ability factor (Hertzog & Schaie, 1988). Thus,

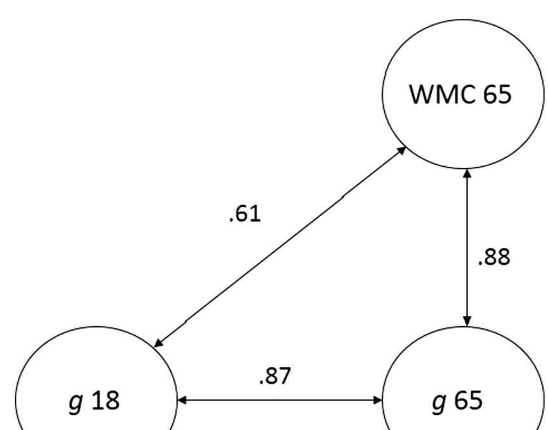

Fig. 2. Concurrent (age 65) and time-lagged (age 18 vs age 65) associations (*r*-values) between general ability and working memory capacity at age 65 (WMC 65).

the individual differences in general cognitive ability established early appear to be well preserved up to young-old age, when an onset of decline tend to be observed and some interindividual differences in intra-individual change is discernible.

One thing that needs to be specified are the neural substrates underlying these patterns and the degree to which trajectories are moderated by other factors (e.g. experience, heath-related, and genetic factors). According to the parieto-frontal integration theory (P-FIT; Jung & Haier, 2007), general intelligence is the result of multiple areas and neuronal networks working in concert, in particular parietal and frontal brain areas. These networks are closely associated with attentional control, and Barbey et al. (2012) found that a *g* factor based on WAIS-subtests was perfectly correlated with an executive functioning factor in a patient sample ($n = 182$). That study further provided evidence that both *g* and executive functions are reliant on regions of frontal and parietal cortex and white matter association tracts, which bind the areas into a coordinated system. In the present study, we confirmed a substantial relationship between *g* and working memory capacity (e.g. Kyllonen & Christal, 1990) which, in turn, has been reported to correlate at $r = .97$ with an executive functioning factor (McCabe, Roediger, McDaniel, Baolota & Hambrick, 2010). Thus, our results seem consistent with the notion that executive control is a key factor to explain individual differences in *g*. From viewpoint of the P-FIT theory, the period from early adulthood up to about 60 years of age might, hence, be characterized by stability in fronto-parietal networks, with a loss of parieto-frontal integrity at a higher age. The latter seems consistent with some functional and structural evidence (Campbell, Grady, Ng, & Hasher, 2012; Park & Reuter-Lorenz, 2009). Atrophy in other areas, for example the hippocampus, may in addition account for some of the age-related decline in a general cognitive factor (Reuben, Brickman, Muraskin, Steffener, & Stern, 2011).

Although strengths of the present study deserve to be highlighted, including a population-based sample with long-term follow-up, it also has limitations. First, even though, as noted by Spearman (1904; "the principle of the indifference of the indicator"), the constellation of measures used to extract a *g* factor may be less important (as long as they are sufficiently varied; Jensen, 1998) as they all to some extent reflect *g*, the use of identical measures of ability in the early and later adulthood would have been optimal (Deary et al., 2000). In addition, the concurrent relationships with established measures of general intelligence or Gf (e.g. WAIS total score or Raven's matrices) is lacking for the ability measures included at present. Furthermore, the fact that the sample was restricted to men may be of concern. To our knowledge, there is however, no evidence of a sex-difference in regard to stability of individual differences in general cognitive ability. Finally, like in most longitudinal studies, some sample attrition was evident. It could hence be argued that the finding of less than perfect stability of interindividual differences over the retest interval from age 50 to age 65, but not at shorter intervals, was due to the fact that the sample of returnees still available at the final retest (67.2% of the total sample) biased the estimate due to being more variable as compared with the entire group of participants. At this point it is warranted to point to the fact that no evidence of selectivity in regard to background variables, nor in ability levels, was evident, and also that the stability coefficient across the 18–50-year period was at least as high (.98) for the subgroup of participants who remained in the study until the final measurement and the entire sample (.95). Thus, as judged from these findings there is no apparent reason why the long-time returnees should bias the stability estimate towards a lower value.

In summary, the present study indicates a remarkable stability of interindividual differences in general cognitive ability from age 18 up to young-old age. Most (>90%) of the variance in general cognitive ability up to age 60 was accounted for by ability at age 18 using a latent variable approach that eliminates measurement error, with indication of a lowered value at age 65. The pattern converges with findings of longitudinal mean-level stability across several cognitive domains up to around age 60, followed by decline and some interindividual differences in change. These patterns may reflect high stability, and subsequent loss of executive control and parieto-frontal integrity, but further research is needed to examine the underlying neural mechanisms and to examine which factors moderate onset of decline and interindividual changes in the *g* factor that occur past age 60.

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References

Barbey, A. K., Colom, R., Solomon, J., Krueger, F., Forbes, C., & Grafman, J. (2012). An integrative architecture for general intelligence and executive function revealed by lesion mapping. *Brain*, *135*(4), 1154–1164.

Campbell, K. L., Grady, C. L., Ng, C., & Hascher, L. (2012). Age differences in the frontoparietal cognitive control network: Implications for distractibility. *Neuropsychologia*, *50*(9), 2212–2223.

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. Cambridge: Cambridge University Press.

Carlstedt, B. (2000). *Cognitive abilities — Aspects of structure, process and measurement*. Unpublished doctoral thesis.

Cheung, G. W., & Renswold, R. B. (2002). *Evaluating goodness-of-fit indexes for testing measurement invariance*.

Conway, A. R. A., Cowan, N., Bunting, M. F., Therriault, D. J., & Minkoff, S. R. B. (2002). A latent-variable analysis of working memory capacity, short-term memory capacity, processing speed, and general fluid intelligence. *Intelligence*, *30*(2), 163–183.

Deary, I. J., Pattie, A., & Starr, J. M. (2013). The stability of intelligence from age 11 to age 90 years: The Lothian birth cohort of 1921. *Psychological Science*, *24*(12), 2361–2368.

Deary, I. J., Whalley, J., Lemmon, H., Crawford, J. R., & Starr, J. M. (2000). The stability of individual differences in mental ability from childhood to old age: Follow-up of the 1932 Scottish survey. *Intelligence*, *28*(1), 49–55.

Deary, I. J., Whiteman, M. C., Starr, J. M., Whalley, L. J., & Fox, H. C. (2004). The impact of childhood intelligence on later life: Following up the Scottish mental surveys of 1932 and 1947. *Journal of Personality and Social Psychology*, *86*(1), 130–147.

Dureman, I. (1960). *SRB:1. Stockholm: psykologiförlaget*.

Hertzog, C., & Schaie, K. W. (1988). Stability and change in adult intelligence: 2. Simultaneous analysis of longitudinal means and covariance structures. *Psychology and Aging*, *3*(2), 122–130.

Jensen, A. R. (1998). *The g factor: The science of mental ability*. Praeger.

Jung, R. E., & Haier, R. J. (2007). The parieto-frontal integration theory (P-FIT) of intelligence: Converging neuroimaging evidence. *Behavioral and Brain Sciences*, *30*(2), 135–187.

Kyllonen, P. C., & Christal, R. E. (1990). Reasoning ability is (little more than) working-memory capacity?! *Intelligence*, *14*(4), 389–433.

McCabe, D. P., Roediger, H. L., III, McDaniel, M. A., Baolota, D. A., & Hambrick, D. Z. (2010). The relationship between working memory capacity and executive functioning: Evidence for a common executive attention construct. *Neuropsychology*, *24*(2), 222–243.

McElree, B. (2001). Working memory and focal attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*(3), 817–835.

Miyake, A., Friedman, N. P., Rettinger, D. A., Shah, P., & Hegarty, M. (2001). How are working memory, executive functioning and spatial abilities related? A latent-variable analysis. *Journal of Experimental Psychology: General*, *130*(4), 621–640.

Nilsson, L. -G., Bäckman, L., Erngrund, K., Nyberg, L., Adolfsson, R., Bucht, G., et al. (1997). The Betula prospective cohort study: Memory, health, and aging. *Aging, Neuropsychology, and Cognition*, *4*(1), 1–32.

Nilsson, L. -G., Adolfsson, R., Bäckman, L., de Frias, C. M., Molander, B., & Nyberg, L. (2004). Betula: A prospective cohort study on memory, health and aging. *Aging, Neuropsychology, and Cognition*, *11*(2–3), 134–148.

Owens, W. A. (1966). Age and mental abilities: A second follow-up. *Journal of Educational Psychology*, *57*(1), 311–325.

Park, D. C., Lautenschlager, G., Hedden, T., Davidson, N. S., Smith, A. D., & Smith, P. K. (2002). Models of visuospatial and verbal memory across the adult life span. *Psychology and Aging*, *17*(2), 229–320.

Park, D. C., & Reuter-Lorenz, P. (2009). The adaptive brain: Aging and neurocognitive scaffolding. *Annual Review of Psychology*, *60*, 173–196.

Plassman, B. L., Welsh, K. A., Helms, M., Brandt, J., Page, W. F., & Breitner, J. C. S. (1995). Intelligence and education as predictors of cognitive state in late life: A 50-year follow-up. *Neurology*, *45*, 1446–1450.

Reuben, A., Brickman, A. M., Muraskin, J., Steffener, J., & Stern, Y. (2011). Hippocampal atrophy relates to fluid intelligence decline in the elderly. *Journal of the International Neuropsychological Society*, *17*(1), 56–61.

Rönnlund, M., & Nilsson, L. -G. (2006a). The Betula study: Reliabilities and long-term stabilities. *Baltic Journal of Psychology*, *7*, 6–14.

Rönnlund, M., & Nilsson, L. -G. (2006b). Adult life-span patterns in WAIS-R block design performance: Cross-sectional versus longitudinal age gradients and relationships to cognitive factors. *Intelligence*, *34*(1), 63–78.

Rönnlund, M., Nyberg, L., Bäckman, L., & Nilsson, L. -G. (2003). Recall of subject-performed tasks, verbal tasks, and cognitive activities across the adult life span: Parallel age-related deficits. *Aging, Neuropsychology, and Cognition*, *10*(3), 182–201.

Rönnlund, M., Nyberg, L., Bäckman, L., & Nilsson, L. -G. (2005). Stability, growth, and decline in adult life span development of declarative memory: Cross-sectional and longitudinal data from a population-based study. *Psychology and Aging*, *20*(1), 3–18.
Schaie, K. W. (1994). The course of adult intellectual development. *American Psychologist*, *49*(4), 304–313.
Schneider, W. J., & McGrew, K. S. (2012). The Cattell–Horn–Carroll model of intelligence. In D. P. Flanagan, & P. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests and issues*. Guilford Press.
Schalke, D., Brunner, M., Geiser, C., Preckel, F., Keller, U., Spengler, M., & Martin, R. (2013). Stability and change in intelligence from age 12 to age 52: Results from the Luxemburg MAGRIP study. *Developmental Psychology*, *49*(8), 1529–1543.
Spearman, C. (1904). "General intelligence" objectively determined and measured. *American Journal of Psychology*, *15*, 201–293.
Strenze, T. (2007). Intelligence and socio-economic success: A meta-analytic view of longitudinal research. *Intelligence*, *35*(5), 401–426.
Unsworth, N., Fukuda, K., Awh, E., & Vogel, E. (2014). Working memory and fluid intelligence: capacity, anttention control, and secondary memory retrieval. *Cognitive Psychology*, *71*, 1–26.
Wechsler, D. (1981). *Wechsler Adult Intelligence Scale — Revised*. San Antonio: The psychological corporation.